Model Rocket Aerodynamics

Stability

- A vehicle will not fly unless aerodynamically stable, i.e. the nose must be pointed in the same direction during its upward flight.
- If unstable, the rocket will fly erratically and will probably crash into the ground. It is also very dangerous!

Center of Gravity

- The *center of gravity* (CG) is the balance point which a free-flying object rotates around. It is the pivot point for the three main forces acting on the rocket:
  - Thrust
  - Air on the Nose
  - Air on the Fins

Center of Gravity

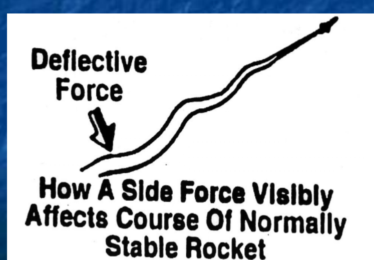
- Off-center thrust and forces on the nose try to bring the nose of the rocket around to the rear. The forces on the fins oppose these forces, straightening the rocket.

Fins

- Fins aerodynamically guide the rocket and keep it stable. The forces on the fins are similar to a balance. If the fins are too small and/or too close to the CG, there will not be enough force to counteract the force on the nose.

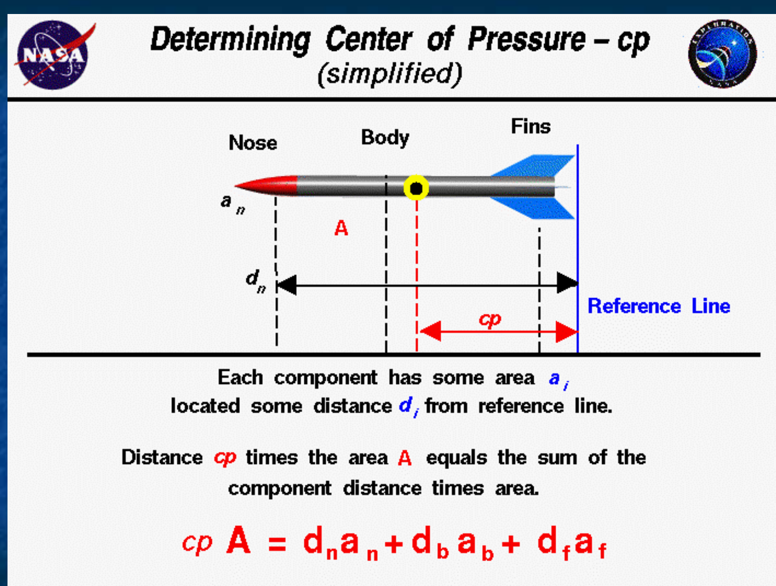
Fins

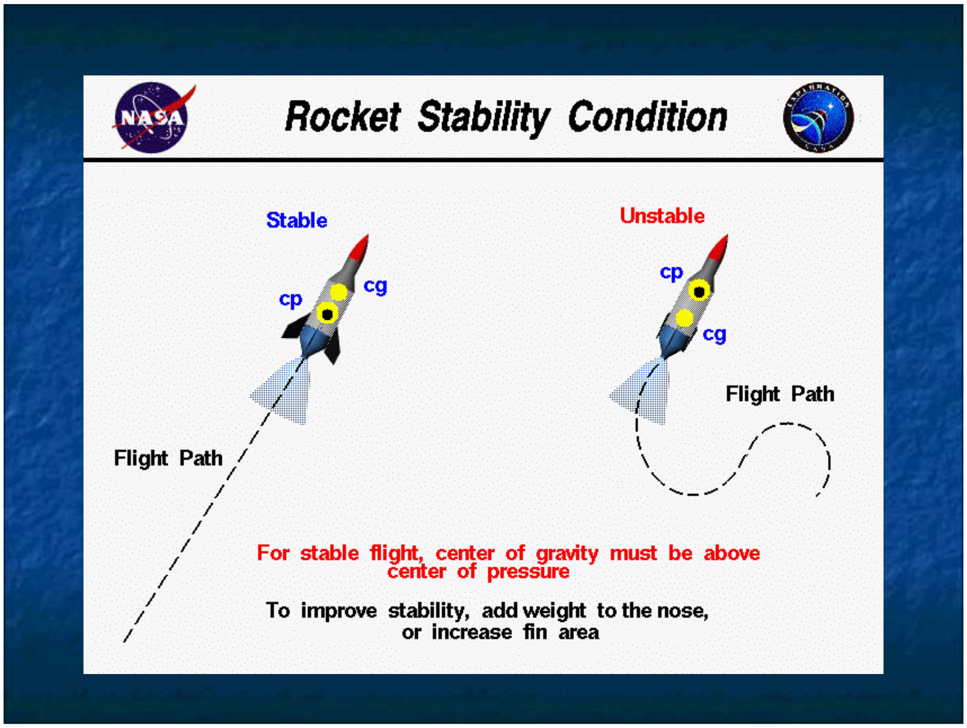
- Occasional disturbances may “rock” the rocket. However, the fins (if properly designed) will swing it back into line.



Center of Pressure

- We can sum up all of the aerodynamic forces on a rocket to a single point called Center of Pressure.



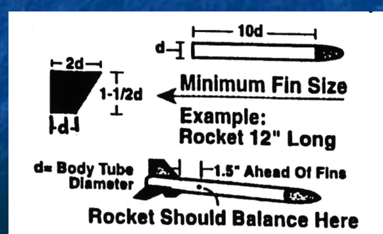


Practical Rules from Experience

- Use a long body, at least 10 times longer than the diameter. This puts distance between the CG and the fins.
- Make the fins large.
  - The larger the fins, the more force that is applied.

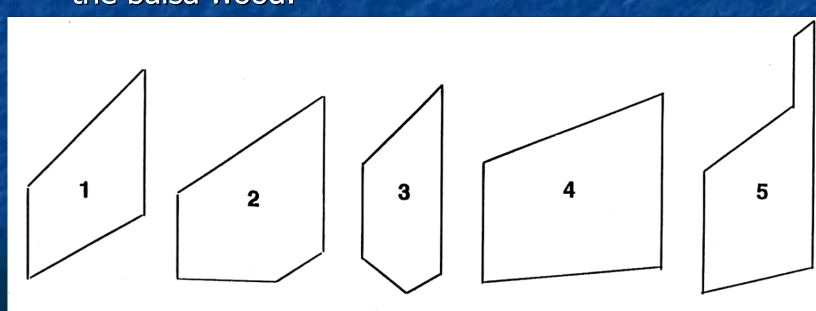
Practical Rules from Experience

- Place the fins as far back on the rocket as possible.
  - Try to keep the engine hook off the ground.
- The rocket should balance at least 1/8 its length ahead of the fins. This gives the fins leverage.



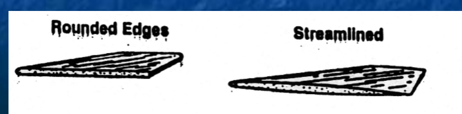
Fin Design

- Use either 3 or 4 fins, all shaped the same and equally spaced.
  - It is helpful to design the fins ahead of time on the graph paper, and then use it as a pattern for cutting the balsa wood.

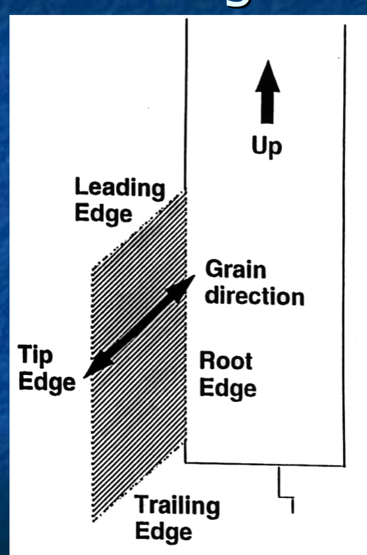


Fin Arrangement

- For maximum strength, the fins must be cut so that the grain of the wood runs parallel with the leading edge.
- In order to improve the performance of your rocket (by reducing drag):
  - Sand the leading (front) edge and tip (side) edge round.
  - Sand the trailing (back) edge to a relatively sharp edge. (Be careful not to make it too thin!)



Fin Arrangement



Parachute Sizing

- Basic rule of thumb

$$v \approx 105\frac{\sqrt{W}}{D}$$

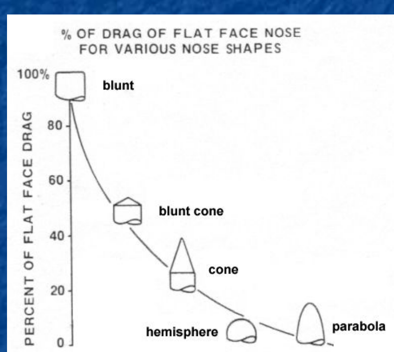
where

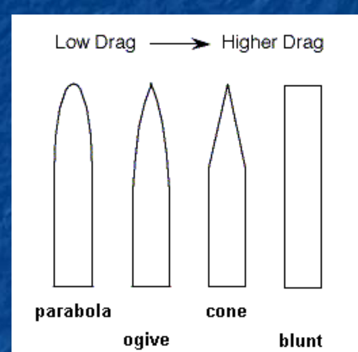
v = descent rate (or velocity) in feet/sec

W = weight in ounces

D = parachute diameter in inches

Nose Cone





Drag

$D = 0.5*\rho*V^2*C_d*S$

r = air density
V = rocket velocity
Cd = drag coefficient (~0.7)
S = reference area (tube cross section)

Things that Increase Drag

- Nose cone shape
- Large fins
- Too many fins
- Long body tube
- Large tube diameter

Things to Reduce Drag

- Choose optimal nose cone shape
- Use smallest fin that will provide adequate stability
- Use smallest diameter tube and nose cone possible
- Streamline the fins
- Use fillets on fins